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SALTY BARK AS A SOIL AMENDMENT

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ABSTRACT

Bark from Douglas-fir logs floated in sea water contained 0.75 to 1.94 percent salt (NaCl). Leaching by natural and simulated rainfall and by soaking readily removed this salt. Bush bean and tomato plants were grown in the greenhouse on a sandy loam soil to which bark of three different proportions of salt was applied as a mulch and as an incorporation at the rate of 40 tons per acre. Mulches containing 0.75 and 1.41 percent salt had little effect on beans but bark containing 1.94 percent salt was slightly depressive; all the incorporations were depressive. Tomato plant yields were reduced by all the bark treatments, most severely by the incorporations.

Use of salty bark at usual rates on the soil can injure salt sensitive plants. Mulches would be less hazardous than incorporations. Chunk sizes would probably cause no toxic effects. Most soil microbes and their essential activities are not likely to be appreciably influenced by salt leached into the soil from salty bark.

Keywords: Forest products research, bark, saline water, plant growth inhibitors.

INTRODUCTION

About 5 million tons of tree bark are produced annually as a byproduct of the wood-using industry of the Pacific States. Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco) is the principal tree species involved. Much of this bark is burned, a practice which can contribute to air pollution in areas of mill concentration. Alternative methods of disposing of tree bark include agricultural or horticultural use as mulch or soil conditioner. Several hundred thousand tons of bark are now being so used.

An appreciable portion of the total production of such bark comes from logs that have been stored or transported in salt water. The salt [1/] content of bark from such logs may be as high as 3.5 percent (table 1), depending on bark moisture content, extent of exposure to sea water, dilution of sea water by fresh water, bark thickness, flotation pattern of the log, scuff marks, dead knots, or marine borer action.

A range of 0.75 to 1.94 percent NaCl was found in a series of samples submitted to us for study (table 2). Logs from which these samples came floated in salt water for periods ranging from 14 to 75 days, then were stored in brackish bay water until sawn.

Agricultural or horticultural use of bark containing appreciable amounts of salt has been questioned. Highly soluble NaCl eventually can leach from the bark into the soil. If all the salt in bark containing NaCl at levels indicated in our samples were to be leached into underlying soil by rain or irrigation, NaCl concentrations of 400 or more parts per million (p.p.m.) might be reached, depending on the depth of soil considered. Toxicity, especially to salt-sensitive plants, might thus develop (Bernstein 1964b).

The main effect of high salinity on plant growth is to make more difficult the uptake of water by plant roots. Factors determining the possibility of reaching toxic levels include initial salt content of bark, bark particle size, amount and distribution of rain or irrigation water, soil type, and kind and age of plant.

Because of the many factors involved, it is difficult to forecast any potential harm to plants that salty bark would

[1/] Throughout this paper "salt" refers to sodium chloride (NaCl). These terms are used interchangeably.

Table 1.--Salt (NaCl) in bark of salt-water-transported logs

Species and weeks in sea	NaCl		
	Log No. 1	Log No. 2	Log No. 3
	Percent		
Douglas-fir:			
3	0.48	0.45	1.32
6	.52	2.22	.74
12	.96	2.04	1.11
25	1.23	--	1.59
Western hemlock:			
2	1.06	1.05	1.07
6	1.54	2.06	1.98
12	--	2.45	3.50
25	--	3.27	--
Western redcedar:			
2	1.58	1.79	1.74
6	2.59	2.44	2.98
12	3.36	3.50	2.84
25	--	1.46	2.00

Source: MacLean, H., and B. F. MacDonald (1968). Salt distribution in sea-water transported logs. Inform. Rep. VP-X-45, 23 p. Forest Prod. Lab., Vancouver, B.C.

Table 2.--Salt (NaCl) in bark from salt-water-floated sample logs

Sample number and species	Total time rafted[1/]	Time stored in salt water	NaCl	
			Investigator's analysis	Commercial laboratory analysis
	--*Months*--	---*Days*---	*Percent*	
1, Douglas-fir	2	14	0.75	0.65
2, Hemlock	2	70	1.16	.98
3, Douglas-fir	4	75	1.56	1.23
4, Hemlock	12	20	1.27	1.31
5, Douglas-fir	11	15	.88	.86
6, Hemlock	11	20	1.29	1.14
7, Douglas-fir	16	15	.80	.70
8, Douglas-fir	--	--	.92	.80
9, Douglas-fir	--	--	.98	1.17
10, Douglas-fir	--	--	1.94	1.80
11, Douglas-fir	--	--	1.41	1.42
12, Douglas-fir	--	--	.86	.85
13, Douglas-fir	--	--	1.44	1.31
14, Douglas-fir	--	--	1.63	1.72

1/ In brackish water at mill.

cause when added to the soil. The salt would be readily dissolved from bark, but the concentration around plant roots would be determined largely by the amount of water applied. Light rainfall or irrigation might only moisten or saturate the bark particles without washing out any salt. Moderate wetting could leach toxic amounts into the upper root zone. On the other hand, greater amounts of water could carry the salt to greater depths and dilute the solution below toxic levels.

The analyses and experiments described in this paper were made to determine the effects on plant growth of applying salty bark to soil, either as a mulch or as an incorporation.

LITERATURE REVIEW

The rate of movement of leached salt into the soil depends largely on soil texture and structure; downward movement would be rapid in sandy soils but very slow in clay soils. Shaw (1927) found that 6 inches of water percolated uniformly throughout a fine sandy loam soil, giving a moisture content of 20 percent, to a depth of 18 inches in 24 days. The temperature-humidity-light complex as affecting transpiration is also important because it influences absorption of NaCl (Lipman et al. 1926, Nieman 1962). Ahi and Powers (1938) found that temperature is a dominant factor in the germination and growth of plants under saline conditions.

The actual concentration of NaCl that would prove injurious in the soil varies with kind and variety of plant, stage of growth, and climatic conditions (Bernstein 1964a, 1964b, U.S. Salinity Laboratory 1954). Chloride exerts specific toxicity to some tree and vine crops, whereas in combination with sodium as NaCl, the effects are more general. The relative tolerance of crop plants to salt places asparagus, cotton, and beets in the high salt tolerant group. Strawberries are very sensitive to salinity (Ehlig and Bernstein 1958). On the other hand, asparagus growth is actually stimulated by salt applications as high as 500 pounds per acre (Rudolfs 1921a). Although 5 to 6 tons of salt per acre is an effective herbicide for many kinds of weeds, absorption of small quantities of chloride ion can stimulate growth (Rudolfs 1921b).

Tomatoes, sweet corn, peas, and some clovers are of medium salt tolerance, while green beans, radishes, and celery are of low salt tolerance. From field plot studies, Bernstein (1964b) found that 1,000 p.p.m. salt reduced a bean crop 10 percent, and tomatoes withstood about 20,000 p.p.m. before a similar reduction in yield occurred. Most plants have more salt tolerance as they approach maturity; they are more easily damaged when they are seedlings.

Salt tolerance of roadside trees along New Hampshire highways salted for deicing has been discussed by Schortle and Rich (1970). Twelve species listed as salt-tolerant showed little or no injury to chloride concentrations ranging from 200 to 11,500 p.p.m. Ten intolerant species were slightly to severely injured by a mean concentration of 9,300 p.p.m. chloride. Considerable variation in salt tolerance was found within as well as between species. Holmes (1961) found that winter road salting probably does no great harm to various hardwoods and white pine in Massachusetts. Damage to white pine from roadside salting has been reported by Smith (1970).

Injury to soil microbes from excessive salt would be detrimental to soil fertility. However, little or no harmful influence of salty bark on soil microbial activities is likely. Most bacteria are relatively insensitive to wide osmotic pressure changes and can adjust to wide changes in the concentration of solutes. Marine bacteria grow in the oceans, containing about 3.5 percent salt; some grow in the Dead Sea containing 25 percent salt, while some halophiles develop on nearly dry sea salt and on salted hides and fish.

Greaves (1916) observed that 5 to 7 p.p.m. NaCl slightly increased ammonification in a sandy loam soil; only much greater concentrations were increasingly depressive, reducing ammonium formation by 90 percent at 5,000 p.p.m. Brown and Johnson (1918) found that ammonification was stimulated by 50 p.p.m. NaCl but was decreased by 100 p.p.m. According to studies by Gibbs, Batchelor, and Magnuson (1925) 1,000 to 4,000 p.p.m. NaCl added to a neutral silt loam soil depressed ammonification and nitrification. Only the highest rate, 4,000 p.p.m., reduced crop yield of wheat in the greenhouse, but a following crop of wheat on the originally treated soils was increased by the residual salt; however, some toxicity to ammonification and nitrification remained. Studies by Brown and Hitchcock (1917) showed that nitrification in normal soils was stimulated by small amounts (50 p.p.m.) of NaCl; above 100 p.p.m., the salt became toxic.

Hendry (1918) found that 2,000 to 8,000 p.p.m. NaCl in liquid added to quartz sand cultures caused injury to bean and cowpea plants and also caused a decrease in the number and size of nodules produced by the symbiotic nitrogen-fixing *Rhizobium* bacteria. In our greenhouse study, salty bark reduced the number of root nodules on inoculated beans in inverse proportion to the NaCl content, while equivalent amounts of sea salt alone almost completely prevented nodulation.

In a clay soil reclaimed from the sea in the Netherlands, Schreven and Harmsen (1968) found that fresh water leached the salt content from about 18 percent to nearly 5 percent, 18 months after the sea had receded. During this time, the bacterial count increased from 65,000 per gram to 15 million; 6 months later this count doubled. In a silt loam soil similarly reclaimed, the salt decreased from about 3.5 percent to nearly zero after 3 years, while the bacteria increased from about 1 million to 60 million per gram. The first period after the sea water had receded was always characterized by an increase in bacteria, the increase being approximately proportional to the decrease in moisture and salt content and the increase in aeration of the soils.

STUDY METHODS

Sample Preparation and NaCl Analysis

Fourteen 10-pound samples of bark from salt-water-transported logs were supplied by Publishers Forest Products Company of Anacortes, Washington.[2/] The samples contained an estimated 10 to 20 percent wood splinters and particles.

Samples were air-dried at 28° C., 31-percent relative humidity, and ground in a Sprout-Waldron single disk attrition mill to pass a 10-mesh sieve. Subsamples taken by quartering were ground in a shatterbox to -100 mesh for NaCl analysis.

Water content was obtained from loss by drying to constant weight at 105° C. All results are expressed on the ovendry basis.

2/ Mention of a company or product does not imply endorsement by the U. S. Department of Agriculture to the exclusion of other companies or products.

Chloride was determined by the lime-fusion method (American Wood Preservers Association 1969). NaCl percentages were calculated from the chloride values.

Leaching Studies

Several trials were made to determine how much and how rapidly NaCl could be leached from the bark.

1. A 50-gram sample, ovendry basis, of bark of a salt-water-floated Douglas-fir log, -10 mesh, 1.41 percent NaCl, 6.83 percent H_2O, was placed in a 1-liter Erlenmeyer flask with enough distilled water to give a 1:10 dilution, mechanically shaken 24 hours, and filtered through Whatman No. 1 paper on a Buchner funnel. The filtrate was analyzed for NaCl. This procedure was repeated four times.

2. From a salt-water-floated Douglas-fir log, 1.44 percent NaCl, a 2-inch layer of -1/2-inch-mesh bark screened from the bulk sample was placed on a 9- by 9-inch wooden frame with a 100-mesh brass screen bottom. This held 985 g. of sample containing 103.1 percent water, the ovendry equivalent being 485 g. The frame with the bark was placed over a pan and sprinkled for 5 minutes with 1,327 ml. distilled water, the equivalent of a 1-inch rainfall over the 9- by 9-inch area. The collected leachate was analyzed for NaCl. This procedure was repeated six times at different times.

3. Salt was leached from 435 g. of bark chunks, ovendry basis, nominally 1- to 2-inch size, 1.63 percent NaCl, 104 percent H_2O, from a salt-water-floated Douglas-fir log, after soaking in 2 liters of distilled water for 24 hours. The bark was then drained and NaCl determined on an aliquot of the drainage after clarification with activated charcoal. NaCl absorbed by the charcoal was found to be negligible. The soaking and draining were repeated seven times.

4. A 2-inch layer of the chunks was exposed to natural rainfall on a 2- by 9- by 10-inch 1/4-inch mesh galvanized screen that fit snugly into the mouth of a polyethylene pail. The percolate was removed for analysis five times within the total period of exposure to 14.4 inches of rain during 54 days from November 18 to January 11.

5. Salt was leached from bark mulch and from soil-incorporated bark from harvested greenhouse pots (table 7).

After beans and tomatoes were grown on soil with a 2-inch mulch of -10-mesh bark from a salt-water-floated Douglas-fir log, 1.41 percent NaCl, and in soil with the bark incorporated at the rate of 40 tons per acre, ovendry basis, the mulch was carefully removed from one of the pots; and 10.0 g. of mulch, ovendry basis, was subjected to extraction for chloride three successive times with 100 ml. distilled water by mechanically shaking 24 hours each time. Each extract was clarified by filtration through Whatman No. 1 paper and analyzed for chloride. Soil under the mulch and soil with bark incorporated were treated in like manner.

All leaching studies were unreplicated; thus, analyses of variance were not possible. It is, however, expected that repeated applications of these studies would produce the same general conclusions.

Plant Growth Studies

To determine if salty bark would have a harmful effect on plant growth, garden beans (Burpee's Stringless Green Pod) and tomatoes (Earlibell) were grown in pots of Newberg sandy loam in the greenhouse. This soil was chosen because it is relatively low in the major nutrients, nitrogen and phosphorus. With such a soil, it was believed the salt effects would be more pronounced.

Six-inch polyethylene pots with drainage holes were filled with 750 g. soil, ovendry basis, and treated in triplicate. Treatments with salt-free bark from the Willamette Valley and sea-salt[3/] in amounts equivalent to NaCl added with the three salty barks used were included for comparison.

In one series, 10 bean seeds, inoculated with *Rhizobium phosaeoli*, were planted in each pot on July 6; when seedlings were 1 to 2 inches tall, they were thinned to three. At the end of September, after 84 days, the plants were cut at ground level, air-dried, and weighed. The roots were harvested separately, air-dried, and weighed. In all cases, the roots were found to be nodulated by the *Rhizobium*.

In a like series of pots, 10 tomato seeds were planted; seedlings were later thinned to three. The plants were harvested in October after 107 days of growth after some flower buds had developed.

All pots were watered with tap water from time to time to keep the soil moist without causing noticeable loss by drainage.

Even in the control pots, plant growth after 6 weeks was not as vigorous as expected, so solutions of ammonium nitrate and monopotassium phosphate were added to each pot at rates of 100 pounds nitrogen, 100 pounds phosphorus, and 126 pounds potassium per acre. This booster had only slight effect.

Harvested tops and roots of bean and tomato plants were air-dried at 28° C., 31-percent relative humidity, and weighed. Sound nodules on bean plant roots also were counted; however, the counts do not represent earlier nodulation because many more or less disintegrated nodules were found. All data were subjected to an analysis of variance.[4/]

Bacterial Tolerance Studies

Thirty-six bacteria were isolated from several different soils by plating procedures (Fred and Waksman 1928), identified (Society of American Bacteriologists 1957, Breed, Murray, and Smith 1957), and tested for growth in nutrient broth containing 2, 7, and 10 percent NaCl.

RESULTS AND DISCUSSION

Leaching Studies

Nearly 90 percent of the salt was removed by the first extraction of bark of a salt-water-floated Douglas-fir log (table 3). All the salt was removed after three extractions.

Sprinkling the bark sample in table 4 with water equivalent to 6 inches of rainfall resulted in removal of more than 90 percent of the salt (table 4). Volume of the first leachate was low, because most of the initial sprinkling was required to saturate the bark. The second leaching removed a major portion of the total salt.

3/ Salt from sun-evaporated sea water. Hain Pure Food Co., Inc., Los Angeles, California.

4/ The design was a one-way analysis of variance with individual treatment effects isolated with a set of orthogonal comparisons. Response surface effects from the levels of salt in water and in bark were analyzed.

Table 3.--Salt (NaCl) extracted from bark sample No. 11,[1/] -10 mesh, by shaking with distilled water[2/]

Extraction number	NaCl	
	In extract	Extracted from bark
	----*Mg*.----	------*Percent*------
1	623	88.5
2	80	11.3
3	2	.3
4	0	.0
Total	705	100.1

1/ 50.0 g., ovendry basis, 1.41 percent NaCl, 6.83 percent H_2O.

2/ 4 successive 24-hour periods, with 1:10 dilution each time.

Table 4.--Salt (NaCl) leached from bark sample No. 13,[1/] -1/2-inch mesh, by successive sprinklings, each simulating 1 inch of rainfall[2/]

Interval between sprinklings	Volume of leachate	NaCl in leachate		Bark NaCl content removed
	--*Ml*.--	-*Mg*.-	*P.p.m.*	-*Percent*-
0 hours	180	652	3,622	9.3
50 "	1,435	4,377	3,050	62.7
24 "	1,000	900	900	12.9
24 "	1,000	370	370	5.3
24 "	980	88	90	1.3
48 "	1,480	59	40	.8
Total	6,075	6,449	1,061	92.3

1/ 1.44 percent NaCl.

2/ 1,327 ml. distilled water from fine spray in 5 minutes each time. Bark layer of 985 g., 2-inch deep by 9- by 9-inch, supported on 100-mesh screen, 103.1 percent H_2O; bark equivalent to 485 g. ovendry basis.

Progressively lesser amounts were removed thereafter until the sixth time, when less than 1 percent salt was found in the leachate. If all the salt leached were uniformly distributed in the surface 6-2/3 inches of a soil and not further diluted by soil moisture, the NaCl concentration would be 1,061 p.p.m.

With the sample bark chunks in table 5, nearly half of all the salt was removed by the first soaking, most of it by three soakings, and essentially all by five successive treatments; less than 1 percent was found in the final removal (table 5). These results indicate that salt in bark chunks also is readily removed by water.

Exposure of bark chunks to natural rainfall also resulted in nearly complete leaching of salt (table 6). During the first 12 days, 4.5 inches of rain leached 81.8 percent of the bark's salt content. Thereafter, the amount of salt leached decreased progressively at a rapid rate. The 14.4 inches of rain during 53 days removed 97.5 percent of the total salt.

During each period, rainfall was collected for chloride determinations. Only during the second and third periods (table 6), which were unusually stormy, was chloride found, equivalent to 1.2 p.p.m. NaCl in each case. This value is close to the mean of those recorded by Ellsworth and Moodie (1964) for rainwater collected during winter months of 1961, 1962, and 1963 at Vancouver, Washington, similar to Corvallis, Oregon, in distance from the ocean.

No appreciable loss of salt occurred when pots containing bark mulch and soil-incorporated bark were watered in the greenhouse (table 7), because the watering regime was adjusted to provide good plant growth without inducing drainage. During the growing season from July to November, the pots were watered about 30 times with 150 to 200 ml. tapwater each time; this kept the soil adequately moist but never oversaturated. This treatment removed 35.7 percent of the bark salt from the mulch. Slightly more than this was recovered from the underlying soil, probably due to sampling rather than analytical errors.

Results of salt removal by the several methods are summarized in table 8. Although the different methods are not directly comparable, it is evident that the salt is more readily removed from finely divided bark which has a greater surface area exposed. However, complete removal of salt from even the chunks can be effected, though more slowly, by more water. Although these experiments were not replicated, it is expected that results from repeated samples would be consistent.

The relative ease with which salt was removed from the bark samples (tables 3-6) was comparable to the rapid rate of removal of salt from polder soils after reclaiming from the Zuyder Zee in the Netherlands (Schreven and Harmsen 1968). After soil was flooded with fresh water for 1 year, crops could be grown on the polders.

Plant Growth Studies

As the amount of salt in bark increased (table 9), growth of tops, roots, and nodules of beans and tops and roots of tomatoes decreased significantly in a linear manner (tables 10, 11).

Comparison of the bark as a mulch with bark incorporated shows that growth of bean tops and tomato tops and roots was significantly lower with bark incorporations. Bean root weights were not different between the two methods of bark application.

Table 5.--Salt (NaCl) soaked from chunks[1/] of bark sample No. 14 by distilled water[2/]

Soaking time	Volume of drainage	NaCl in drainage		Bark NaCl content removed
	--Ml.--	*-Mg.-*	*P.p.m.*	*-Percent-*
1 day	1,800	3,431	1,906	47.1
1 day	1,910	1,077	564	14.8
1 day	1,915	1,702	889	23.4
10 days	1,510	598	396	8.2
16 days	1,330	299	225	4.1
13 days	1,390	118	85	1.6
12 days	1,570	61	39	.8
Total	11,425	7,286	--	[3/]102.8

1/ 1- to 2-inch nominal dimension, 435 g., 1.63 percent NaCl.

2/ 7 successive soakings, with 2-liter volumes each time.

3/ Total NaCl removed slightly exceeds 100 percent of that originally present, due to accumulation of positive analytical errors.

Table 6.--Salt (NaCl) leached from chunks[1/] of bark sample No. 14, by rainfall

Exposure number and time	Rainfall		NaCl in leachate		Bark NaCl content leached
	Volume	Volume of leachate			
	Inches	*--Ml.--*	*-Mg.-*	*P.p.m.*	*-Percent-*
1st, 12 days	4.5	6,660	7,066	1,060	81.8
2d, 8 days	3.1	5,020	783	156	9.1
3d, 15 days	2.2	3,170	304	96	3.5
4th, 6 days	3.5	5,220	188	36	2.2
5th, 12 days	1.1	1,700	77	45	.9
Total, 53 days	14.4	21,770	8,418	[2/]387	97.5

1/ 1 to 2 inches (nominal dimension) 2 inches deep on 9- by 10-inch, 1/4-inch mesh screen; 530 g., 1.63 percent NaCl.

2/ In total leachate volume.

Table 7.--Salt (NaCl) in bark mulch,[1] soil,[2] and combination[3]

Extraction number	NaCl			
	Found[4]	In total mulch, 32.1 g.		
		Found[4] x 32.1/10	Original	Extracted
Bark mulch:[1]	*--Mg.--*	*---Mg.---*	*---Mg.---*	*-Percent-*
1	43.9	140.9	--	33.3
2	3.1	10.0	--	2.4
3	.0	.0	--	.0
Total	47.0	150.9	423	35.7

Extraction number	NaCl				
	Found[4]	In total soil, 750 g.		In soil and mulch	
		Found[4] x 750/20		Added	Found[4]
Soil under mulch:[2]	*--Mg.--*	*--Mg.--*	*-P.p.m.-*	*--Mg.--*	*--Mg.--*
1	7.3	273.8	365	--	--
2	.6	22.5	30	--	--
3	.0	.0	0	--	--
Total	7.9	296.3	[5]395	423	447

Extraction number	NaCl				
	Found[4]	In total soil plus bark		Added to soil by bark	
		Found[4] x 780/20			
Soil with bark incorporated:[3]	*--Mg.--*	*--Mg.--*	*-P.p.m.-*	*--Mg.--*	*-P.p.m.-*
1	10.7	417.3	535	--	--
2	.6	23.4	30	--	--
3	.0	.0	0	--	--
Total	11.3	440.7	565	423	564

[1] Mulched with 2 inches -10-mesh bark sample No. 11, 1.41 percent NaCl, at 40 tons per acre. 10.0 g. mulch subjected to extraction 3 successive 24-hour periods with 100 ml. water each time, on mechanical shaker. NaCl determined on total filtrate through Whatman No. 1 paper on Buchner funnel.

[2] Salt in soil under mulch. 20.0 g. extracted as for the mulch.

[3] Soil plus bark sample No. 11, -10 mesh, at 40 tons per acre incorporated. 20.0 g. extracted as for mulch.

[4] Found by chemical analysis.

[5] Leached from mulch by watering in the greenhouse 30 times with 150 to 200 ml. water each time during 114 days. Represents 64.3 percent of NaCl originally present in the mulch.

Table 8.--Influence of bark particle size on amount of salt (NaCl) removed by leaching or soaking

Particle size	NaCl	NaCl content removed
	Percent	
-10 mesh	1.41	[1]100.1
-10 mesh	1.41	[2]64.3
-1/2-inch mesh	1.44	[3]92.3
1- to 2-inch mesh	1.63	[4]97.5
1- to 2-inch mesh	1.63	[5]102.8

[1] By 3 successive 24-hour 1:10 extractions with distilled water (table 3).

[2] By leaching from 2-inch mulch, -10-mesh bark in greenhouse, watering 20 times with 150 ml. each time during 114 days (table 7).

[3] Three successive simulated 1-inch rainfalls in laboratory at 24-hour intervals (table 4).

[4] 14.4 inches of rainfall, 53 days (table 6).

[5] Soaking by 7 successive 2-liter volumes distilled water (table 5).

Table 9.--Soil treatments for study of effect of Douglas-fir salt-free and salty bark[1] on growth of bean and tomato plants in the greenhouse

Treatment	NaCl in bark	NaCl added to soil
	Percent	*P.p.m.*
Soil only	0.00	0
Mulches at 40 tons per acre:		
Inland bark	0.00	0
Bark No. 7	.75	300
Bark No. 11	1.41	564
Bark No. 10	1.94	776
Incorporated at 40 tons per acre:		
Inland bark	.00	0
Bark No. 7	.75	300
Bark No. 11	1.41	564
Bark No. 10	1.94	776
Sea salt alone:		
Sea salt[2]	--	300
Sea salt[2]	--	564
Sea salt[2]	--	776

[1] -10 mesh.

[2] 99 percent NaCl.

Table 10.--Dry weight yield of bean plant tops and roots in the greenhouse

Treatment	NaCl added to soil	Dry weight[1]		Root nodules[1]
		Tops	Roots	
	--P.p.m.-	*G.*		*Number*
Soil only	0	5.33	0.93	5
Mulches:				
Inland bark	0	6.40	.98	7
Bark No. 7	300	5.67	.93	4
Bark No. 11	564	5.43	.97	3
Bark No. 10	776	4.33	.68	2
Incorporations:				
Inland bark	0	4.03	1.13	8
Bark No. 7	300	4.33	1.13	5
Bark No. 11	564	3.20	.77	2
Bark No. 10	776	2.80	.73	3
Sea salt alone:				
Sea salt	300	3.87	.63	0
Sea salt	564	2.33	.35	1
Sea salt	776	2.30	.28	0

1/ Mean of three pots.

Table 11.--Dry weight yield of tomato plants in the greenhouse

Treatment	NaCl added to soil	Dry weight[1]	
		Tops	Roots
	----P.p.m.----	*G.*	
Soil only	0	1.03	0.22
Mulches:			
Inland bark	0	.37	.12
Bark No. 7	300	.44	.18
Bark No. 11	564	.50	.20
Bark No. 10	776	.63	.23
Incorporations:			
Inland bark	0	.03	.03
Bark No. 7	300	.04	.02
Bark No. 11	564	.01	.01
Bark No. 10	776	.01	.01
Sea salt alone:			
Sea salt	300	.67	.13
Sea salt	564	.56	.10
Sea salt	776	.57	.09

1/ Mean of three pots.

A test was made for the presence of a bark treatment by salt interaction. The presence of such an interaction would identify a difference in the response of the plants under the different salty bark treatments to increasing levels of salt. Growth response of tomato tops and roots to salt in bark was significantly different for bark mulch as opposed to bark incorporation. Lesser growth with incorporated bark is believed due to nitrogen deficiency induced by bark mixed with the soil. A mulch is in contact only with the surface of the soil and exerts little immediate influence on nutrition of microbes in the bulk of the soil. Thus, there is little if any competition with plant roots for available nitrogen as would occur with an incorporation of any material having a wide carbon-to-nitrogen ratio.

With sea salt alone, yields of bean tops and roots decreased linearly as salt concentration increased. Tomato top and root growth differences were not statistically significant.

Yields of bean tops, roots, and nodules were significantly less for the average level of sea salt alone applied to the soil than for the average levels of salt in bark. Bernstein and Ayers (1951) observed that green beans had the lowest degree of salt tolerance found in any of the number of truck crops tested. Salt in bark, even though readily leached, may not enter the soil solution as readily as does free salt. Tomato top yields were appreciably reduced by all the bark mulches; the incorporations were much more restrictive.

Not only did the bark mulches lessen depressive influence of the salt but also apparently allowed stimulation by the chloride ion which may have liberated some plant nutrients by an exchange process (Greaves 1916; Rudolfs 1921a, 1921b).

Bacterial Studies

In the presence of 10 percent NaCl, 26 of the isolants grew well; eight grew in the 7-percent concentration but failed to develop in 10 percent NaCl; and only two failed to grow at NaCl concentrations of 2 percent and above (table 12). This indicates that many of the common soil bacteria would not be inhibited by the maximum possible NaCl concentration leached from salty bark applied to the soil.

Salt Tolerance of Soil Molds

Tresner and Hayes (1971) recently reported the NaCl tolerance of 975 species of terrestrial fungi. Only a few of these could tolerate less than 5 percent NaCl; species of *Penicillium* and *Aspergillus*, usually the most abundant molds in soil, were most resistant and the majority were able to grow in the presence of 20 percent or more NaCl.

CONCLUSIONS

Percent of NaCl found in bark from salt-water-floated Douglas-fir logs ranged from 0.75 to 1.94. This salt is readily leached by rainfall or irrigation. Use of such bark for mulching or soil conditioning at usual rates of about 40 tons per acre could result in injury to salt-sensitive plants if leaching was sufficient only to concentrate the salt in the upper root zone. Salty bark ground to nominal 1/4- to 1/2-inch size commonly used for horticultural purposes offers less hazard as a mulch than as an incorporation. Chunk sizes used for walkways and decorative purposes would probably have no toxic effects. Salt leached from salty bark mulches or incorporations would have no appreciable effect on soil microbes and their essential activities.

Field trials with different kinds of plants under a variety of conditions will be required for more definite recommendations on the safe use of salty bark.

Table 12.--Tolerance of some common soil bacteria for salt (NaCl)

Bacterium	Number of isolants tested	NaCl percent concentration		
		2	7	10
Bacillus agrestis	1	—	—	—
Bacillus badus	1	+	—	—
Bacillus cereus	3	+	+	+
Bacillus coagulans	2	+	+	—
Bacillus firmus	2	+	+	+
Bacillus laterosporus	2	+	+	+
Bacillus megaterium	2	+	+	+
Bacillus pumulis	1	+	+	+
Bacillus subtilis	8	+	+	+
Bacillus subtilis aterrimus	2	+	+	+
Bacillus subtilis niger	1	+	+	+
Micrococcus capsulatus	1	—	—	—
Micrococcus caseolyticus	1	+	+	+
Mycobacterium brevicale	1	+	+	+
Pseudomonas geniculata	1	+	+	—
Soil diphtheroid	5	+	+	+
Soil diphtheroid	2	+	+	—

NOTE: — indicates no growth. + indicates growth comparable to that in nutrient broth containing no added NaCl.

LITERATURE CITED

Ahi, S. M., and W. L. Powers.
1938. Salt tolerance of plants at various temperatures. Plant Physiol. 13: 767-789.

American Wood Preservers Association.
1969. Determination of chloride for calculating pentachlorophenol in oil or wood. Standard Methods A5. Washington, D. C.

Bernstein, Leon.
1964a. Reducing salt injury to ornamental shrubs in the West. U. S. Dep. Agr. Home Gard. Bull. 95, 6 p., illus.

____
1964b. Salt tolerance of fruit crops. U. S. Dep. Agr. Agr. Inform. Bull. 292, 8 p., illus.

__________ and A. D. Ayers.
1951. Salt tolerance of six varieties of green beans. Proc. Amer. Soc. Hort. Sci. 57: 243-248.

Breed, Robert Stanley, E. G. D. Murray, and N. R. Smith.
1957. Bergey's manual of determinative bacteriology. 7th ed. 1094 p. Baltimore: Williams & Wilkins Co.

Brown, P. E., and D. R. Johnson.
1918. Effects of certain alkali salts on ammonification. Iowa State Coll. Agr. Exp. Sta. Res. Bull. 44, 24 p., illus.

__________ and E. B. Hitchcock.
1917. The effects of alkali salts on nitrification. Soil Sci. 4: 207-229.

Ehlig, C. F., and L. Bernstein.
1958. Salt tolerance of strawberries. Proc. Amer. Soc. Hort. Sci. 72: 198-206.

Ellsworth, Norma, and C. D. Moodie.
1964. Nutrient inputs in rainfall at nine selected sites in Washington. Wash. Agr. Exp. Sta. Interim Rep. Proj. 1670, 9 p. plus unnumbered tables, illus.

Fred, E. B., and S. A. Waksman.
1928. Laboratory manual of general microbiology. 145 p., illus. New York: McGraw-Hill Book Co.

Gibbs, W. M., H. W. Batchelor, and H. P. Magnuson.
1925. The effects of alkali salts on bacteriological activities in soil. III. Ammonification, nitrification, and crop yield. Soil Sci. 19: 371-379.

Greaves, J. E.
1916. The influence of salts on the bacterial activities of the soil. Soil Sci. 2: 443-480.

Hendry, G. W.
1918. Relative effect of sodium chloride on the development of certain legumes. J. Amer. Soc. Agron. 10: 246-249.

Holmes, Francis W.
1961. Salt injury to trees. Phytopathology 51: 712-719, illus.

Lipman, E. B., A. R. Davis, and E. S. West.
1926. The tolerance of plants for NaC1. Soil Sci. 22: 303-322.

MacLean, Harold, and B. F. MacDonald.
1968. Salt distribution in sea-water transported logs. Inform. Rep. VP-X-45, 23 p. Forest Prod. Lab., Vancouver, B. C.

Nieman, Richard H.
1962. Some effects of sodium chloride on growth, photosynthesis, and respiration of twelve crop plants. Bot. Gaz. 123: 279-285.

Rudolfs, W.
1921a. Experiment with common rock salt. I. Effect on asparagus. Soil Sci. 12: 449-455.

______ 1921b. Experiments with common rock salt. II. Eradication of weeds and cleaning of roadsides with salt. Soil Sci. 12: 457-470.

Schortle, W. C., and A. E. Rich.
1970. Relative sodium chloride tolerance of common roadside trees in southeastern New Hampshire. Plant Dis. Rep. 54(5): 360-362.

Schreven, D. A. van, and G. W. Harmsen.
1968. Soil bacteria in relation to the development of polders in the region of the former Zuider Zee. In The ecology of soil bacteria. T. R. G. Gray and D. Parkinson, eds., p. 474-499. 681 p., illus. Toronto: Univ. Toronto Press.

Shaw, Charles F.
1927. The normal moisture capacity of soils. Soil Sci. 23: 303-317, illus.

Smith, William H.
1970. Salt contamination of white pine planted adjacent to an interstate highway. Plant Dis. Rep. 54: 1021-1025, illus.

Society of American Bacteriologists.
1957. Manual of microbiological methods. H. J. Conn, ed. 315 p., illus. New York: McGraw-Hill Book Co.

Tresner, H. D., and Jean A. Hayes.
1971. Sodium chloride tolerance of terrestrial fungi. Appl. Microbiol. 22:210-213.

U.S. Salinity Laboratory.
1954. Diagnosis and improvement of saline and alkali soils. L. A. Richards, ed. U.S. Dep. Agr. Agr. Handb. No. 60, 160 p., illus.

GPO 795-382

Bollen, W. B.
1971. Salty bark as a soil amendment. USDA Forest Service Res. Pap. PNW-128, 16 p. Pacific Northwest Forest & Range Experiment Station, Portland, Oregon.

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